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CLAIMS

[Claim(s)]

[Claim 1]A modeling device comprising:

A position measurement means which measures a position of the tip part concerned and a supporter about a model object which has a joint linked to two or more tip part and these tip parts, such as a fingertip, and a supporter which supports the tip part concerned via said joint. A model data generating means which generates model data of said model object based on position information on each tip part measured by this position measurement means and a supporter.

It has a model data output means which outputs model data generated by this model data generating means to external instruments, such as a displaying means. A restraint condition storage part said model data generating means remembered a constraint about flexibility and angle of rotation of said joint which were beforehand defined according to an example of said model object of operation to be.

A geometric model synchronizer which compounds a geometric model for every tip part generated by geometric model generation part which computes a position of the tip part concerned and the tip part concerned, and an angle of a linked joint, and this geometric model generation part for every tip part based on a constraint stored in this restraint condition storage part, and position information on said tip part.

[Claim 2]The modeling device comprising according to claim 1:

The 1st constraint storage area that memorizes the 1st constraint as which said restraint condition storage part determined a relation of an angle of each joint beforehand about one tip part and two or more linked joints.

A full-size degree calculation function in which said geometric model generation part computes from a supporter a relation of an angle of each joint which exists by a tip part based on a position of a supporter measured by said position measurement means, and a position of said tip part when the 1st constraint is imposed about a tip part which generates a model.

[Claim 3]It has the 2nd constraint storage area that memorizes the 2nd constraint fixed at an angle which gave flexibility only to a joint with said restraint condition storage part specific about one tip part and two or more linked joints, and was beforehand defined about other joints. Said geometric model generation part, When the 2nd constraint is imposed about a tip part which generates a model, by said position measurement means. Compute an angle of a joint specified by the 2nd constraint of the inner above of each joint which exists by a tip part from the supporter concerned based on a position of a measured supporter, and a position of said tip part, and. The modeling device according to claim 1 or 2 provided with a specific joint angle calculation function judged to be the angle beforehand defined about other joints.

[Claim 4]Said restraint condition storage part, It has the 3rd constraint storage area that memorizes a tip part and a joint used as a standard by which an angle of each joint linked to a position of an unmeasured tip part by which a position is not measured by the inner aforementioned position measurement means of a tip part of said model object, and the

unmeasured tip part concerned was defined beforehand as the 3rd constraint, Said geometric model generation part, When said 3rd constraint is imposed on an unmeasured tip part which generates a model, judge a position which follows a position of a tip part used as a standard of the unmeasured tip part concerned to be a position of the unmeasured tip part concerned, and, The modeling device according to claim 1, 2, or 3 provided with an unmeasured partial calculation function computed based on an angle of the unmeasured tip part concerned, a tip part which serves as said standard about an angle of each linked joint, and each linked joint.

[Claim 5] A position metering device which measures a position of the tip part concerned and a supporter about a model object which has two or more tip parts, such as a fingertip, these tip parts, a linked joint, and a supporter which supports the tip part concerned via said joint, An arithmetic unit which generates model data of said model object based on position information on each tip part which is connected with this position measurement means and inputted from the position measurement means concerned, A modeling system provided with constraint memory storage which memorized a constraint about flexibility and angle of rotation of said joint which were beforehand defined according to an example of a model object of operation is used. A constraint reading command to which are the storage which memorized a program for modeling data generation for generating modeling data in real time, and a constraint stored in said restraint condition storage part is made to read for every kind of said tip part, Geometric model generation instructions which make a position of the tip part concerned and the tip part concerned, and an angle of a linked joint compute for every tip part based on a constraint read according to this constraint reading command, and position information on said tip part, A storage which memorized a program for modeling data generation provided with geometric model composition instructions which make a geometric model for every tip part generated according to these geometric model generation instructions compound.

[Claim 6] The 1st constraint data that is provided with the following and said restraint condition storage part makes equal [an angle of each joints of two or more] about an index finger model and a middle finger model, The 2nd restricted data fixed at an angle which gave flexibility only to a joint which hits the root of the thumb concerned about a thumb model, and was beforehand defined about other joints, It has a restricted data storage area provided with the 3rd restricted data that defined flattery form of making operation of said middle finger model following about a third finger model and a digitus-minimus model, A modeling device, wherein said geometric model generation part is provided with an approximation shape calculation function which computes shape of each of said fingertip model based on one ingredient in three dimensional coordinates of said fingertip position, and said each restricted data.

A position measurement means which a fingertip position of the thumb, an index finger, and the middle finger is measured among the digiti-manus point positions concerned by using shape of a hand of an operator as a model object, and computes three dimensional coordinates of the fingertip position concerned.

A model data generating means which generates geometric model data of a hand which consists of a fingertip model which has a joint based on position information on each tip part measured by this position measurement means, and the back of a hand.

It has a model data output means which outputs geometric model data of a hand generated by this model data generating means to external instruments, such as a displaying means, A restraint condition storage part said model data generating means remembered a constraint about flexibility and angle of rotation of each joint of each finger beforehand defined according to an example of said fingertip model of operation to be.

A model-synthesis part which compounds a geometric model generation part which generates a fingertip model for every finger based on a constraint stored in this restraint condition storage part, and position information on said tip part, and a fingertip model for every tip part generated by this geometric model generation part and a shell model of said hand.

[Translation done.]

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DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[Field of the Invention]This invention relates to a modeling device and relates to the modeling device which generates a geometric model in real time especially by using operation of human being's hand, a motion of an animal, etc. as a model object.

[0002]The model object which is the target of geometric model generation by this invention is provided with the joint connected with a tip part and this tip part, and the supporter which supports a tip part via this joint. If it is a thing which has this tip part and joint, various things, such as a living body and an object on the imagination to an inorganic substance pan, can be used as a model object. That is, this invention is suitable for generation of the geometric model of 4 foot-actuation things, such as a geometric model of the hand which uses a fingertip as a tip part, and a horse which uses the point of a leg as a tip part, the geometric model of the trees which use a leaf tip as a tip part, and the geometric model of a folding umbrella.

[0003]As an applicable field of this invention, it is applicable to the general computer graphics technology in a virtual reality. The simulation of an operation and the application to a game can be considered.

[0004]

[Description of the Prior Art]Conventionally, displaying operation of a hand on a display in real time is performed. For example, the technique of operating the object in virtual space is indicated by JP,H10-207617,A by the same applicant using the three-dimensional input manipulator.

[0005]

[Problem(s) to be Solved by the Invention]However, in the example indicated by the above-mentioned gazette, irrespective of the shape of the hand under operation, the model of the hand displayed on a display lengthened the index finger, and actually showed it in the shape in the state where other fingers were grasped. Then, there was inconvenience that the state of the hand displayed that the shape of the model of a hand is constant on the state and display of a hand of an operator will be different to being what gives the reaction force from a virtual model to three fingertips, for example.

[0006]Although it is considered as the technique of carrying out the modeling of the state of a hand and motion capture is mentioned, this does not display real time. Although there is a method of attaching a distortion sensor to the finger joint part of a glove, and detecting the bend condition of each finger in real time, there is inconvenient [that a motion of a finger is restrained not a little].

[0007]

[Objects of the Invention]This invention improves the inconvenience which the starting conventional example has, and it sets as the purpose providing the modeling device which can generate the geometric model of the model object concerned in real time, securing natural operation of the model object in which shape becomes settled by the tip part and a joint especially.

[0008]

[Means for Solving the Problem] In this invention, in order not to interfere in natural operation of a model object but to know a state of a model object, only a tip part and a supporter perform position Measurement Division. And it emulates from a position of a tip part, and a position of a supporter about angle of rotation, a direction, etc. of a joint which connects each tip part and a supporter, without carrying out direct measuring. Since there are few measure points, a constraint is given [as opposed to / at this time / a total of flexibility of each joint] to angle of rotation of each joint according to that difference. What is made equal [angle of rotation of a joint connected with one tip part for example] as a constraint, a relation which it is twice the relation between a joint angle of a certain joint and a joint angle of other joints of this, or numerals of plus or minus reverse, etc. correspond.

[0009] A position measurement means which measures a position of the tip part concerned, and a position of a supporter which supports the tip part concerned via said joint about a model object which specifically has the joint linked to two or more tip part and these tip parts, such as a fingertip, by this invention. A model data generating means which generates model data of said model object based on position information on each tip part measured by this position measurement means and a supporter. It has a model data output means which outputs model data generated by this model data generating means to external instruments, such as a displaying means. And a restraint condition storage part a model data generating means remembered a constraint about flexibility and angle of rotation of said joint which were beforehand defined according to an example of said model object of operation to be, A geometric model generation part which computes a position of the tip part concerned and the tip part concerned, and an angle of a linked joint for every tip part based on a constraint stored in this restraint condition storage part, and position information on said tip part. Composition of having had a geometric model synchronizer which compounds a geometric model for every tip part generated by this geometric model generation part is taken. It is going to attain the purpose which this mentioned above.

[0010] A position measurement means measures a position of each tip part of a model object, and a position of a supporter. And in a model data generating means, a geometric model generation part generates model data based on position information on this tip part, and position information on a supporter. Since there is few position information measured to a joint number at this time, a constraint about flexibility and angle of rotation of a joint is used. This constraint is beforehand stored in a restraint condition storage part, and a geometric model generation part reads and uses a constraint stored in this restraint condition storage part. Geometric model data of a complicated model object which has a joint by little position information by using this constraint is generated.

[0011]

[Embodiment of the Invention] Hereafter, an embodiment of the invention is described with reference to Drawings. The modeling device by this embodiment is provided with the following. The position measurement means 2 which measures the position of the tip part concerned and a supporter about the model object 22 which has the joint linked to two or more tip part and these tip parts, such as a fingertip, and a supporter which supports the tip part concerned via said joint.

The model data generating means 1015 which generates the model data of said model object based on the position information on each tip part measured by this position measurement means 2 and a supporter.

The model data output means 1011 which outputs the model data generated by this model data generating means 1015 to external instruments, such as a displaying means.

The restraint condition storage part 1012 the model data generating means 1015 remembered the constraint about the flexibility and angle of rotation of said joint which were beforehand defined according to the example of said model object 22 of operation to be, The geometric model generation part 1013 which computes the position of the tip part concerned and the tip part concerned, and the angle of the linked joint for every tip part based on the constraint stored in this restraint condition storage part 1012, and the position information on said tip part. It has the geometric model synchronizer 1014 which compounds the geometric model for every

tip part generated by this geometric model generation part 1013.

[0012]The model object is made into the shape of people's hand in the example shown in drawing 1. For this reason, the position measurement means 2 measures the position of the fingertip which is a tip part of a hand. In the example shown in drawing 1, the marks 21B thru/or 21F used as the feature on Image Processing Division are given to the fingertip, and the position of each mark is measured by the principle of triangulation. For this reason, the position measurement means 2 is provided with the following.

The imaging camera 23 which photos the hand containing a fingertip.

The light source 24 which irradiates a hand with measurement light.

In this case, the geometric model generation part 1015 computes the distance to each mark based on the angle which a light source and the imaging camera 23 accomplish, and the image pickup position of each mark, and it is provided with the image processing function which changes the distance to each of this mark into the coordinates in the coordinate system in a measuring object. This image processing function changes the coordinate value of each point in a camera coordinate system into the coordinate value in object frame. By this image processing function, a three-dimensional range finder can be used as a three dimensional position metering device. Although the three dimensional position metering device by Image Processing Division is adopted as the position measurement means 2, it may be made to use other sensors which detect the amount of displacement and speed of not only this but a fingertip in the example shown in drawing 1.

[0013]If the position of each fingertip which is a tip part which stands in a row at a joint is measured, the geometric model generation part 1015 will generate the model data of a hand based on the position information on each of this fingertip. At this time, the geometric model generation part 1015 uses various constraints, in order to emulate the shape of a hand. That is, detecting position information only by a fingertip, since the shape becomes settled at three joints, the finger cannot specify angle of rotation of each joint by single position information. For this reason, a constraint is given according to the character of operation of each finger.

[0014]Drawing 2 is a block diagram showing the relation of the constraint data and each function of the geometric model generation part 1014 which are stored in the restraint condition storage part 1012. The restraint condition storage part 1012 is provided with the 1st constraint storage area that memorizes the 1st constraint 1021 that defined the relation of the angle of each joint beforehand about one tip part and two or more linked joints first. Assumption that the 1st constraint has one tip part and the same angle of two or more linked joints, for example, and the assumption about the size ratio of each angle correspond. Such assumption is good to set according to the character of a model object. For example, if it is an index finger of people's hand, though angle of rotation of each joint is the same, the geometric model to generate will be in a natural state. The size ratio of each angle is the 2nd joint when the 1st joint is set to a [rad], for example. $a/2$ The constraint set to [rad] is meant.

[0015]When the 1st constraint is imposed according to this 1st constraint about the tip part in which the geometric model generation part 1014 generates a model, it has the full-size degree calculation function 1016 which computes from a supporter the relation of the angle of each joint which exists by a tip part based on the position of the supporter measured by the position measurement means 2, and the position of said tip part. Namely, in the example shown in drawing 1, angle of rotation of three joints is computed by using a fingertip as a tip part using two position information.

[0016]The restraint condition storage part 1012 is provided with the 2nd constraint storage area that memorizes the 2nd constraint fixed at the angle which gave flexibility only to the joint specific about one tip part and two or more linked joints next, and was beforehand defined about other joints. Even if this 2nd constraint is a case where two or more joints which support a tip part exist, it is conditions of restraining at the angle which gave flexibility only to the specific joint and was beforehand defined about other joints.

[0017]When the 2nd constraint is imposed according to this 2nd constraint about the tip part in which the geometric model generation part 1013 generates a model, Based on the position of the supporter measured by the position measurement means 2, and the position of said tip part, The

angle of the joint specified by the 2nd constraint of the inner above of each joint which exists by a tip part from the supporter concerned is computed, and it has the specific joint angle calculation function 1017 judged to be the angle defined beforehand about other joints. The number of specific joints becomes settled according to the number of measure points, the number of joints, and the number of flexibility. It is good to use this 2nd constraint for generation of the geometric model of the thumb in the example shown in drawing 1. Since angle of rotation of three joints is specified using the position information on two points, the fingertip of the thumb, and a supporter, the fingertip side specifies angle of rotation of two joints beforehand, and after limiting flexibility for the root of the thumb in the one direction, angle of rotation is computed here based on the measured position information.

[0018]The restraint condition storage part 1012 further, By the inner aforementioned position measurement means 2 of the tip part of the model object 22. It has the 3rd constraint storage area 1023 that memorizes the tip part and joint used as the standard by which the angle of each joint linked to the position of the unmeasured tip part by which a position is not measured, and the unmeasured tip part concerned was defined beforehand as the 3rd constraint. This is a constraint for not measuring a position about the tip of a digitus minimus, but, for example, making the shape of a digitus-minimus model, and operation follow the shape of the model of the third finger, and operation. This 3rd constraint is provided with the following.

The flattery conditions of the position which specifically computes the amount of displacement of a digitus-minimus fingertip based on the amount of displacement of a third finger fingertip. The flattery conditions of the angle which makes angle of rotation which each joint of the third finger computed angle of rotation of each joint of a digitus minimus.

[0019]Said geometric model generation part, When said 3rd constraint is imposed on the unmeasured tip part which generates a model, judge the position which follows the position of the tip part used as the standard of the unmeasured tip part concerned to be a position of the unmeasured tip part concerned, and. The modeling device according to claim 1, 2, or 3 provided with the unmeasured partial calculation function computed based on the angle of the unmeasured tip part concerned, the tip part which serves as said standard about the angle of each linked joint, and each linked joint.

[0020]Drawing 3 is a block diagram showing the composition of the hardware resources of this embodiment. The model data generating means 1015 and the model data output means 1011 which are shown in drawing 1 are realizable by computers (arithmetic processing unit), such as a workstation. The arithmetic processing unit 1010 is provided with the following.

Measurement Division I/F1031 which receives the image data picturized by the imaging camera 23 which constitutes a part of position measurement means.

CPU1037 which performs processing which the coordinate value of the fingertip of each finger is computed based on this image data, and generates the geometric model of each finger based on the coordinate value concerned.

RAM1038 used as the main memory of this CPU1037.

ROM1039 which memorized the procedure at the time of starting of the arithmetic processing unit 1010, etc.

[0021]Input-and-output I/F1033 which manages input and output with the hard disk 1034 and disk drive 1035 grade according to control according [the arithmetic processing unit 1010] to CPU1037 further, The disk drives 1035, such as a CD-ROM drive which reads the program data concerned from storages, such as CD-ROM in which the program for modeling data generation was stored, When this program for modeling data generation is installed, it has the hard disk (HD) 1034 which memorizes the file which constitutes this program. CPU1037 is executing this program for modeling data generation, and functions as the model data generating means 1015 shown in drawing 1. Constraint data as shown in drawing 2 is stored in the hard disk 1034, and it functions on it as constraint memory storage.

[0022]The arithmetic processing unit 1010 is provided with the display interface 1032 used as an interface with the display which displays again the geometric model data generated by CPU1037

on a display. Display I/F1032 has RAM for a display, is performing depiction processing of a polygon, etc., and functions as the model data output means 1011 shown in drawing 1.

[0023] The program for modeling data generation stored in the storage is provided with the following.

The constraint reading command to which the constraint stored in the hard disk 1034 is made to read for every kind of said tip part as instructions for operating said CPU1037.

Geometric model generation instructions which make the position of the tip part concerned and the tip part concerned, and the angle of the linked joint compute for every tip part based on the constraint read according to this constraint reading command, and the position information on said tip part.

Geometric model composition instructions which make the geometric model for every tip part generated according to these geometric model generation instructions compound.

[0024] When calling it "instructions to operate" here, either or the both sides of the instructions which operate an arithmetic processing unit only by each instructions, and the instructions which operate the computer concerned depending on other programs, such as an operating system beforehand stored in the arithmetic unit, is included. For example, in the example shown in drawing 3, geometric model generation instructions read the constraint data stored in the hard disk depending on the file input output function of an operating system. Therefore, geometric model generation instructions are instructions which read to an operating system and hand over the target file name, for example. Thus, it is a storage which memorizes the program for analytic-model generation concerned, and "instructions which reads to an operating system and hands over the target file name" may be stored in the storage of the use which conveys the program concerned to a user, for example. This becomes settled in a relation with the operating system etc. of the computer which it is going to operate.

[0025] Lighting Sub-Division 24 irradiates with measurement light the hand 22 which is a model object. The imaging camera 23 receives the catoptric light from this hand 22, and inputs shade image data into Measurement Division I/F1031. CPU1037 computes the distance of the fingertips 21B thru/or 21F from this shade image data first. For example, based on the angle of Lighting Sub-Division 24 and the imaging camera 23 to accomplish, the principle of triangulation generates a depth map from a shade image, and it may be made to compute the coordinates of each fingertip further by extracting the portion according to the radius of circle of the fingertip among depth maps. Whether each radius-of-circle portion is equivalent to which finger gives which finger each radius of circle is by the initial condition, and it is specified after next Measurement Division of which finger it is a fingertip according to the amount of displacement of each radius-of-circle portion from the last measuring position. A respectively individual mark is given to the fingertip instead of extraction of a radius-of-circle portion, and it may be made to specify according to the image recognition. In order to give reaction force to a fingertip, the operation input means 2A in working example mentioned later is used.

[0026] If the coordinates of each fingertip are specified, CPU1037 will read the constraint according to each finger from the hard disk 1034. The 2nd constraint 1022 is read in calculation of a thumb model. And angle of rotation of the root of the thumb is computed. It attaches by a digitus minimus from an index finger, and the 1st constraint is read. And the angle of each joint of one finger is a premise made equal, and computes a joint angle for every finger. Then, from the fingertip position of each finger, and the angle of a joint, CPU1037 generates the link used as the skeleton of the model of a hand, forms the cylindrical shape which makes this link a medial axis, and forms the shape defined beforehand in accordance with the direction of a finger about the back of a hand. Thereby, the geometric model of a hand is formed. A geometric model of this sort is displayed on a display via display I/F1032. By repeating Measurement Division of these fingertip coordinates, and generation of a geometric model with a predetermined sampling period, the modeling of the operation of the hand which is a model object can be carried out in real time.

[0027]

[Example] Next, working example of this invention is described with reference to Drawings. At this

example, the modeling of the shape of a hand is carried out by measuring three positions of the fingertip position of the thumb, an index finger, and the middle finger. In the index finger model and middle finger model which are geometric models of an index finger and the middle finger, formed data is generated using the 1st constraint that each joint angle is the same. Flexibility is given only to the joint of the root of the thumb about the thumb, and the 2nd constraint made into the angle defined beforehand is used about other joints. About a third finger model and a digitus-minimus model, the 3rd constraint made to follow the formed data of the middle finger is used. To a motion of the hand of the operator which is a measuring object, real time can be followed, the geometric model data of the hand that this has five tip parts and a finger which has three joints, respectively can be generated, and it can display on external instruments, such as a display.

[0028] In this example, the geometric model of a hand is arranged in virtual space, it displays on a display, and reaction force is given to a fingertip according to interference with a geometric model of this sort and other models in virtual space. If a glove etc. are used at this time, in order to restrain a motion of a hand greatly, in this example, the operation input means (refer to drawing 6 thru/or drawing 8) which restrains only the back of a fingertip and a hand is used.

[0029] Drawing 4 is a flow chart which shows the outline of the geometric model creation processing by this example. In this example, sensing of the position of the fingertip of the position and posture of the back of a hand, and the thumb, an index finger and the middle finger is performed first (Step S1). In the link coordinate system of the hand shown in drawing 5, the coordinates of the white round head (σ_1 thru/or σ_3) of a tip part are measured, and, on the other hand, it does not measure about σ_4 and σ_5 which are black dots. And since only sensor data cannot perform modeling to the flexibility of each joint, the following constraint can be added (Step S2). As a constraint, first, it fixes, and two joints of the thumb are root (circumference of a Z-₋₁₁-axis)-accepted, and rotate. Next, the angle of rotation of each three joint of an index finger and the middle finger is equal. And the third finger and a digitus minimus follow operation of the middle finger.

[0030] According to these constraints, the locus of the fingertip on a link coordinate system becomes settled. Then, a joint angle is determined using one ingredient of the sensor data (x, y, z) of a fingertip (step S4, approximation shape calculation function). Parallel translation of the two ingredients from which a fingertip differs is carried out, and they are amended. The position of each joint is also proportioned in the distance from the root of a finger, and parallel translation is carried out (Step S5). A polygon is stretched and displayed on the surroundings of each link cylindrical.

[0031] Next, the composition which gives reaction force to a fingertip using the operation input means 2A and this is explained. Drawing 6 is the operating grip 21A holding the fingertip of the thumb, an index finger, and the middle finger. The operating grip 21A is provided with the cap member 211 in which the tip part of a finger is inserted, and the two arm members 212, 213 formed in the approximate circle arc of 90 angles which form what is called a gimbal mechanism. And the end part engages with the cap member 211 centering on a perpendicular direction, enabling free rotation, and, as for the arm member 212, the other end is engaging with the end part of the arm member 213 centering on a horizontal direction, enabling free rotation. An engaging end with the arm member 212 and a rotating shaft with the arm member 212 and the end of an opposite hand cross at right angles, and the arm member 213 is connected with the tip part of the link member 21A centering on the vertical direction, enabling free rotation.

[0032] By taking this composition, rotation of the cap member 211 is attained centering on three directions with which receive the link member 25A and directions and a gap also cross at right angles, and irrespective of the angle of gradient of the link member 25A, where the fingertip of an operator is turned in the arbitrary directions, it can be held. The cap member 211 is good also as a ring member which inserts a fingertip only in addition to the composition shown in drawing 6, for example.

[0033] Drawing 7 is a perspective view showing the composition of the modeling device by this example which has the function to give reaction force to a fingertip. The operation input means

which give predetermined flexibility, and three operating grips are supported in this example, respectively, and measures the position and posture of a shell of a hand, It has the input means movement energizing mechanism 4B which reduces the inertia force by the mass of an operation input means by moving this operation input means itself according to the position of the hand of an operator. The operation input means 4B and the input means movement energizing mechanism 4B are provided with the drive-motor group for giving reaction force and moving an operation input means, the encoder group which measures angle of rotation of a link, etc., etc. The input means movement energizing mechanism 4B is provided with the direct-acting type link member 44B in order to move an operation input means not only rotational movement but within a predetermined radius. Operation of this direct-acting type link member 44 is detected by the direct-acting type potentiometer.

[0034] The arithmetic processing unit 1010 which the coordinates of a fingertip are computed based on outputs, such as each encoder of the operation input means 2A and an input means movement energizing mechanism, and generates the model data of a hand further in this example, It has the display 1001 which displays the geometric model data of the hand generated by this arithmetic processing unit 1010 with other virtual bodies. The modeling device is provided with the control means 3B which controls operation of an operation input means and the input means movement energizing mechanism 4B. The three-dimensional manipulator 10B is constituted by the operation input means 2A, the input means movement energizing mechanism 4B, and the control means 3B.

[0035] Drawing 8 is a block diagram showing the composition of the control system of the three-dimensional manipulator 10B shown in drawing 7. The input coordinate calculation part 31 which computes the input position coordinates of each operating grip 21A of every based on the direct-acting displacement signal detected by the detection angle signal from which the control means 3B is detected by each encoder, and the potentiometer, It has the motion-control part 32 which outputs the operating command signal based on this input position coordinate data to the input means movement energizing mechanism 4B, and the reaction force generating control section 33 which inputs a drive command signal into the drive-motor group of an operation input means based on the reaction force data outputted from the arithmetic processing unit 1010.

[0036] If angle of rotation of each rotation joint 2Aa of the alter operation means 2A, 2Ab, and 2Ac becomes clear, the position of the operating grip which makes rotation joint 2Ac a reference position can be found. In order to change this coordinate system into the coordinate system centering on a model object, a homogeneous transformation procession is used. If the coordinate value in the coordinate system of each alter operation means 2A of every is changed into the coordinate value in a model object, it will become a coordinate value of the tip part for generating a geometric model. Also about inclination by the position and normal coordinate of a shell of a hand, it computes from the angle of rotation of the rotation joint of the operation input means 2A.

[0037] If this coordinate value is obtained, the arithmetic processing means 1010 will generate the model of a finger using a constraint. Drawing 9 is an explanatory view showing the example which displayed the geometric model data generated by this example on the display. By using the position information on the back of a fingertip and a hand, and a predetermined constraint, the shape of a natural hand as shown in drawing 9 is generable. Hereafter, based on the link coordinate system (here, a left hand is illustrated) of the hand shown in drawing 5, the constraint and the calculation technique at the time of generating this model are explained.

[0038] First, the posture of the back of a hand is searched for by making the position of the back of a hand into the starting point. Coordinate value σ_1 of the tip part of the thumb, an index finger, and the middle finger, σ_2 , and σ_3 are computed.

[0039] The homogeneous transformation procession in the link coordinate system of the thumb is shown in a formula (1). Here (O_{11} , O_{12} , and O_{13}), The offset coordinate value of the starting point of a Z_{11} axis, C_{ij} and S_{ij} $\cos\theta_{ij}$, $\sin\theta_{ij}$. As for C_{ij} and S_{ij} , $\cos(\theta_{i1}+\theta_{i2})$, $\sin(\theta_{i1}+\theta_{i2})$, C_{123} , and S_{123} express $\cos(\theta_{i1}+\theta_{i2}+\theta_{i3})$ and $\sin(\theta_{i1}+\theta_{i2}+\theta_{i3})$.

theta_i expresses the angle of rotation of link L_{1i} of the circumference of a Z_{1i} axis. Thereby, the coordinates of the fingertip of the thumb are shown by the following formula (2).

[0040]

[Equation 1]

$${}^0T_1 = \begin{bmatrix} -c_1 & s_1 & 0 & O_{11} \\ 0 & 0 & 1 & O_{12} \\ s_1 & c_1 & 0 & O_{13} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$${}^1T_2 = \begin{bmatrix} \frac{1}{\sqrt{2}}c_2 + \frac{1}{2}s_2 & -\frac{1}{\sqrt{2}}s_2 + \frac{1}{2}c_2 & -\frac{1}{2} & L_{11} \\ \frac{1}{\sqrt{2}}s_2 & \frac{1}{\sqrt{2}}c_2 & \frac{1}{\sqrt{2}} & 0 \\ \frac{1}{\sqrt{2}}c_2 - \frac{1}{2}s_2 & -\frac{1}{\sqrt{2}}s_2 - \frac{1}{2}c_2 & \frac{1}{2} & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$${}^2T_3 = \begin{bmatrix} c_3 & -s_3 & 0 & L_{12} \\ s_3 & c_3 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$${}^0T_3 = \begin{bmatrix} -\frac{1}{\sqrt{2}}c_{123} - \frac{1}{2}c_1s_{23} & \frac{1}{\sqrt{2}}s_{123} - \frac{1}{2}c_1c_{23} & \frac{1}{\sqrt{2}}s_1 + \frac{1}{2}c_1 & -L_{12}(\frac{1}{\sqrt{2}}c_{12} + \frac{1}{2}c_1s_2) - L_{11}c_1 + O_{11} \\ \frac{1}{\sqrt{2}}c_{123} - \frac{1}{2}s_{123} & -\frac{1}{\sqrt{2}}s_{123} - \frac{1}{2}c_{123} & \frac{1}{2} & L_{12}(\frac{1}{\sqrt{2}}c_2 - \frac{1}{2}s_2) + O_{12} \\ \frac{1}{\sqrt{2}}s_{123} + \frac{1}{2}s_1s_{23} & -\frac{1}{\sqrt{2}}c_{123} + \frac{1}{2}s_1c_{23} & \frac{1}{\sqrt{2}}c_1 & L_{12}(\frac{1}{\sqrt{2}}s_{12} + \frac{1}{2}s_1s_2) + L_{11}s_1 + O_{13} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

--- (1)

$${}^0T_3 = \begin{bmatrix} L_{13} \\ 0 \\ C \\ 1 \end{bmatrix} = \begin{bmatrix} -L_{13}(\frac{1}{\sqrt{2}}c_{123} + \frac{1}{2}c_1s_{23}) - L_{12}(\frac{1}{\sqrt{2}}c_{12} - \frac{1}{2}c_1s_2) - L_{11}c_1 + O_{11} \\ L_{13}(\frac{1}{\sqrt{2}}c_{23} - \frac{1}{2}s_{23}) + L_{12}(\frac{1}{\sqrt{2}}c_2 - \frac{1}{2}s_2) + O_{12} \\ L_{13}(\frac{1}{\sqrt{2}}s_{123} + \frac{1}{2}s_1s_{23}) + L_{12}(\frac{1}{\sqrt{2}}s_{12} + \frac{1}{2}s_1s_2) + L_{11}s_1 + O_{13} \\ 1 \end{bmatrix}$$

--- (2)

[0041] A following formula (3) shows the homogeneous transformation procession in each link coordinate system of an index finger, the middle finger, the third finger, and a digitus minimus. Here, y is a subscript showing a finger and 3 and the third finger are [an index finger / 4 and the digitus minimus of 2 and the middle finger] 5. (O_{y1}, O_{y2}, and O_{y3}) The offset coordinate value of the starting point of a Z_{y1} axis, costheta_y, sintheta_y, C_{yj}, and S_{yj}; C_i and S_i cos (theta_{i1}+theta₂), As for sin (theta_{i1}+theta₂), C₁₂₃, and S₁₂₃, cos (theta_{i1}+theta₂+theta₃), sin (theta_{i1}+theta₂+theta₃), C_y, and S_y express cos (alpha_y) and sin (alpha_y). theta_i expresses the angle of rotation of link L_{yi} of the circumference of a Z_{yi} axis. Thereby, the coordinates of the fingertip of an index finger, the middle finger, the third finger, and a digitus minimus are shown by the following formula (4).

[0042]

[Equation 2]

$$\begin{aligned}
 {}^0T_1 &= \left[\begin{array}{ccc|c} -S_y c_1 & S_y s_1 & C_y & O_{y1} \\ C_y c_1 & -C_y s_1 & S_y & O_{y2} \\ s_1 & c_1 & 0 & O_{y3} \\ \hline 0 & 0 & 0 & 1 \end{array} \right] \\
 {}^1T_2 &= \left[\begin{array}{ccc|c} c_2 & -s_2 & 0 & L_{y1} \\ s_2 & c_2 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ \hline 0 & 0 & 0 & 1 \end{array} \right] \\
 {}^1T_3 &= \left[\begin{array}{ccc|c} c_3 & -s_3 & 0 & L_{y2} \\ s_3 & c_3 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ \hline 0 & 0 & 0 & 1 \end{array} \right] \\
 {}^0T_3 &= \left[\begin{array}{ccc|c} -S_y c_{123} & S_y s_{123} & C_y & -S_y(L_{y2}c_{12} + L_{y1}c_1) + O_{y1} \\ C_y c_{123} & -C_y s_{123} & S_y & C_y(L_{y2}c_{12} + L_{y1}c_1) + O_{y2} \\ s_{123} & c_{123} & 0 & L_{y2}s_{12} + L_{y1}s_1 + O_{y3} \\ \hline 0 & 0 & 0 & 1 \end{array} \right]
 \end{aligned}$$

----- 式 (3)

$${}^0T_3 \begin{bmatrix} L_{y3} \\ 0 \\ 0 \\ \hline 1 \end{bmatrix} = \begin{bmatrix} -S_y(L_{y3}c_{123} + L_{y2}c_{12} + L_{y1}c_1) + O_{y1} \\ C_y(L_{y3}c_{123} + L_{y2}c_{12} + L_{y1}c_1) + O_{y2} \\ L_{y3}s_{123} + L_{y2}s_{12} + L_{y1}s_1 + O_{y3} \\ \hline 1 \end{bmatrix}$$

----- 式 (4)

[0043]Next, the equation which asks for the joint angle of the thumb is explained. If the coordinates of the fingertip of the thumb obtained by a sensor are made into (P_{1x}, P_{1y}, P_{1z}) , the relation of a following formula (5) will be obtained from a formula (2). Here, the coordinates of the left side express the point on the link coordinate system assumed suitably, and the solution with which all of three formulas of the left side are filled does not exist probably. That a solution certainly exists is a case where the state of a finger is searched for only using one of the coordinates acquired by the sensor. For the purpose, it is necessary to set a state variable to one. Then, the following constraints are added in order to search for the joint angle of the thumb.

[0044]It fixes and the joint angle of the circumference of the 2nd constraint Z_{12} and a Z_{13} axis

gives flexibility only to the circumference of a Z_{11} axis. The equation of this 2nd constraint and the 1st equation to the equation (6) of an equation (5) is obtained. Here, a_1 , a_2 , and a_3 are constants shown in a formula (7). A formula (8) will be obtained, if a formula (6) is made into $a_1c_1+a_3=-a_2s_1$, both sides are squared and it arranges about c_1 . A formula (9) will be obtained if c_1 is calculated from a formula (8). Considering the movable range of the thumb, the state of the thumb in the assumed link coordinate system becomes settled uniquely from a formula (9).

[0045]

[Equation 3]

$$\begin{bmatrix} -L_{13}(\frac{1}{\sqrt{2}}c_{123} + \frac{1}{2}c_1s_{23}) - L_{12}(\frac{1}{\sqrt{2}}c_{12} - \frac{1}{2}c_1s_2) - L_{11}c_1 + O_{11} \\ L_{13}(\frac{1}{\sqrt{2}}c_{23} - \frac{1}{2}s_{23}) + L_{12}(\frac{1}{\sqrt{2}}c_2 - \frac{1}{2}s_2) + O_{12} \\ L_{13}(\frac{1}{\sqrt{2}}s_{123} + \frac{1}{2}s_1s_{23}) + L_{12}(\frac{1}{\sqrt{2}}s_{12} - \frac{1}{2}s_1s_2) + L_{11}s_1 + O_{13} \end{bmatrix} = \begin{bmatrix} P_{1x} \\ P_{1y} \\ P_{1z} \end{bmatrix} \quad \text{----- 式 (5)}$$

$$a_1c_1 + a_2s_1 + a_3 = 0 \quad \text{----- 式 (6)}$$

$$\begin{aligned} a_1 &= L_{13}(\frac{1}{\sqrt{2}}c_{23} + \frac{1}{2}s_{23}) + L_{12}(\frac{1}{\sqrt{2}}c_2 + \frac{1}{2}s_2) + L_{11} \\ a_2 &= -\frac{1}{\sqrt{2}}(L_{13}s_{23} + L_{12}s_2) \\ a_3 &= P_{1x} - O_{11} \end{aligned} \quad \text{----- 式 (7)}$$

$$(a_1^2 - a_2^2)c_1^2 + 2a_1a_3c_1 + (a_3^2 - a_2^2) = 0 \quad \text{----- 式 (8)}$$

$$c_1 = \frac{-a_1a_3 \pm \sqrt{a_2^2(a_1^2 + a_2^2 - a_3^2)}}{a_1^2 + a_2^2} \quad \text{----- 式 (9)}$$

[0046]The equation which asks for the joint angle of an index finger is explained. If the fingertip coordinates of the index finger obtained by a sensor are made into (P_{2x}, P_{2y}, P_{2z}) , the relation shown in a formula (10) will be obtained from a formula (4). In order to draw the equation with which a solution certainly exists like the case of the thumb, we decided to add the following constraints.

[0047] The joint angle of the circumference of a 1st constraint Z_{21} , Z_{22} , and Z_{23} axis is equal. If $\cos\theta_{21} = \cos\theta_{22} = \cos\theta_{23} = c$, the equation of an equation (11) will be obtained from this 1st constraint from the 2nd equation of an equation (10). Here, a_1 , a_2 , and a_3 are constants shown in a formula (12). If the movable range of an index finger is considered and this 3rd equation is solved, a solution will serve as an equation (13) and will be given to a meaning. Here, A_1 and A_2 are constants shown by a formula (14). This relation is the same also about the middle finger.

[0048]

[Equation 4]

$$\begin{bmatrix} -S_{21}(L_{23}c_{123} + L_{22}c_{12} - L_{21}c_1) + O_{21} \\ C_2(L_{23}c_{123} + L_{22}c_{12} + L_{21}c_1) + O_{22} \\ L_{23}s_{123} + L_{22}s_{12} + L_{21}s_1 + O_{23} \end{bmatrix} = \begin{bmatrix} P_{2X} \\ P_{2Y} \\ P_{2Z} \end{bmatrix}$$

式(11)

$$c^3 + a_1c^2 + a_2c + a_3 = 0$$

式(12)

$$a_1 = \frac{L_{22}}{2L_{23}}$$

$$a_2 = \frac{L_{21}}{4L_{23}} - \frac{3}{4}$$

$$a_3 = -\frac{1}{4L_{23}}(L_{22} + \frac{P_{2Y} - O_{22}}{C_2})$$

式(12)

$$c = \sqrt[3]{\sqrt{\frac{A_1^3}{27} + \frac{A_2^3}{4}} - \frac{A_2}{2}} - \sqrt[3]{\sqrt{\frac{A_1^3}{27} + \frac{A_2^3}{4}} + \frac{A_2}{2}} - \frac{a_1}{3}$$

式(13)

$$A_1 = -\frac{a_2^2}{3} + a_2$$

$$A_2 = -\frac{2a_1^3}{27} - \frac{a_1a_2}{3} + a_3$$

式(14)

[0049] By asking for a joint angle from the position coordinate of a fingertip using this formula (8) and (13), the geometric model of a hand can be created in comparatively few measure points. That is, in order not to restrain operation of a hand or to make detection of a position easy, the modeling data of the shape of a natural hand as shown in drawing 9 can be created by the tip part of a fingertip, the position of a shell, and detection of only a posture.

[0050] As shown in drawing 7, in order to detect only the fingertip position of three points, the middle finger is made to follow about the positions and shape of a third finger model and a digitus-minimus model in this example using the 3rd constraint. That is, all the joint angles of the joint of a digitus minimus and the joint of the third finger compute that it is the same as that of the joint angle of the middle finger.

[0051] If the link coordinates for every finger become settled with the technique mentioned above, the cylinder side which makes a medial axis the link shown in drawing 5 is formed, it will be giving a hemisphere about a fingertip and finger model data will be generated. It is made to rotate about the portion of the back of a hand to the posture which measured the shape defined beforehand. The geometric model data of a hand is generated by computing the sum of each of this finger model and the model of the portion of the back of a hand.

[0052]

[Effect of the Invention] It is that a geometric model generation part uses the constraint stored in this restraint condition storage part according to this since this invention is constituted as mentioned above and functions, In order to generate the geometric model data of the complicated model object which has a joint by little position information, Since the geometric model data of the complicated shape which has a joint based on the position information only on the tip part which does not restrict operation of a model object can be generated and load is not given to each joint of the model object at all, By being able to make natural operation continue, measuring position information with a predetermined sampling period, and generating geometric model data. The outstanding modeling device which is not in the former that the geometric model according to operation of the model object can be generated, for example, it can input into a display etc. can be provided.

[Translation done.]

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DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1]It is a block diagram showing the composition of the embodiment of this invention.

[Drawing 2]It is a block diagram showing the detailed composition of the restraint condition storage part and geometric model generation part which were shown in drawing 1.

[Drawing 3]It is a block diagram showing the composition of the hardware resources of the modeling device shown in drawing 1.

[Drawing 4]It is a flow chart which shows the outline which generates the model data of a hand according to one working example of this invention.

[Drawing 5]It is an explanatory view showing the link coordinate system of the hand used by this example.

[Drawing 6]It is a perspective view showing the composition of the operating grip used by this example.

[Drawing 7]It is a perspective view showing the composition of an alter operation means to use it by this example.

[Drawing 8]It is a block diagram showing the composition of the control system of the three-dimensional manipulator shown in drawing 7.

[Drawing 9]It is an explanatory view showing the display example of the geometric model data of the hand generated by this example.

[Description of Notations]

2A Position measurement means (operation input means)

23 Imaging camera

24 Lighting Sub-Division

1001 Display

1011 Model data output means (display I/F)

1012 Restraint condition storage part (for example, hard disk)

1013 geometric model generation part (for example, CPU)

1014 geometric model synchronizer (for example, CPU)

1015 Model data generating means

[Translation done.]

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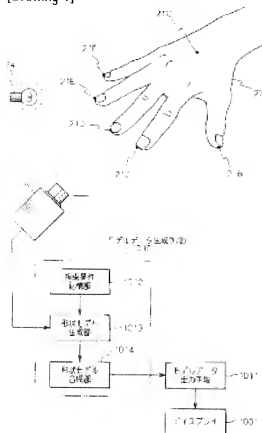
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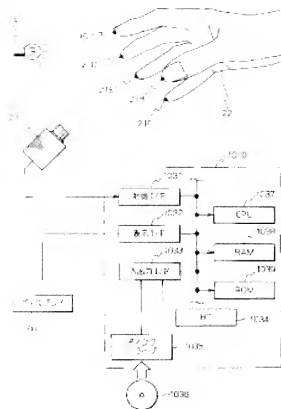
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DRAWINGS

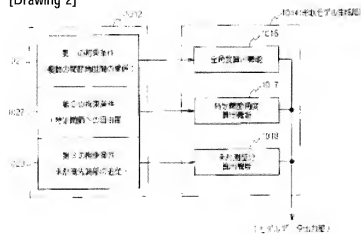
[Drawing 1]



[Drawing 3]



[Drawing 2]



[Drawing 4]

[Drawing 9]



[Translation done.]